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JPL Contract 951709

STERILIZABLE LIQUID PROPULSION SYSTEM

Ninth Quarterly Progress Report

Author

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April 1969

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This work was performed for the Jet Propulsion Laboratory, California Institute of Technology, sponsored by the National Aeronautics and Space Administration under Contract NAS7-100.

NOTICE

MCR-67-15
(Issue 9)

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FOREWORD

This document is the ninth issue of the Quarterly Progress Report and is submitted in accordance with Article 1(a)(1)(v)(H) and 2(c)(3) of modification No. 1 to JPL Contract 951709.

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I. INTRODUCTION

This is the ninth quarterly progress report submitted in accordance with JPL Contract 951709. This report covers the period from 1 January through 31 March 1969.

The program has included the design, assembly, and exposure of a fueled bipropellant liquid propulsion system to the ethylene oxide (ETO) and heat sterilization environments required by JPL specification VOL 50503 ETS. After exposure the system was successfully fired for 280 seconds. The program was supported by a materials compatibility test program and component verification program wherein suitability of all selected components was demonstrated prior to system assembly.

Under an extension to the contract the system is being refurbished and will be subjected to additional heat sterilization prior to an additional test firing. Design changes have been made to the oxidizer tank and the expulsion diaphragm. These design changes were described in an earlier issue of the quarterly report. The fuel tank screen trap was also modified to eliminate two-phase flow from the tank when expelling in a negative 1-g regime.

During the report period the oxidizer tanks and rebuild of the Teflon diaphragms were completed and the re-assembly of the propulsion module was initiated. The continuing materials test program was completed and the evaluation of results was documented.

II. CONCLUSIONS

As a result of the work performed during this period the following conclusions can be made.

1. Anodic coatings of aluminum alloys insures a very high degree of protection of these materials.
2. Cladding aluminum alloys with pure aluminum provides satisfactory protection.
3. Tantalum, columbium, tungsten and the ceramics were unaffected by the N_2O_4.
4. Nickel is a major cause of the corrosion of the 300 series stainless steels.

III. RECOMMENDATIONS

1. Permeation of helium through Teflon must be considered in system design allowance.
2. Further permeation testing of the various Teflon formulations for both helium and nitrogen should be performed. Much scatter now exists in the data which are not yet published.
3. Adequate size and space must be provided to prevent spray build up in tight places of the diaphragm mandrel.
4. Further development should be carried out to determine the effect on induction heating and sealing of Teflon coated parts.

IV. GENERAL REPORT

A. The Materials Test Program

Background

A continued materials test program produced a number of interesting and valuable results which will serve to broaden the technology developed in the first series of tests conducted in the fourth quarter of 1966 and reported in the second Quarterly Report, April 1967, and Part I of the final report August 1968. Earlier tests produced sufficient materials data to allow design and functional operation of a sterilizable engine module which was loaded with propellants prior to heat sterilization. Materials tested in 1966 exhibited varying degrees of resistance to N_2O_4 at 275°F after 600 hours. A brief summary of those results are listed below:

(a) Titanium alloy 6Al-4V possessed the highest degree of resistance to the propellant. This alloy was used for the propellant tanks.

(b) All structural aluminum alloys tested were found to sustain both surface and intergranular attack (up to 4 mills deep) with production of finely divided aluminum oxide and aluminum nitrate salts.

(c) The 300 series stainless steels were attacked both at the surface and at grain boundaries to a depth of about 0.004". This attack caused the formation of massive quantities of a thick viscious amorphous product which contained the same elements as the parent material.

(d) All high nickel alloys were attacked destructively and produced large quantities of semi-liquid corrosion products.

(e) Teflon was lightly attacked with the production of a white flock with no significant change in the physical properties of the material.

The additional materials compatibility test specimens were selected to evaluate a variety of basic alloys not considered previously and to determine whether protective coatings could be used on materials subject to attack. Other considerations included evaluation of ductile metals for screen devices and the importance of nickel, as an alloying agent, on the corrosion resistance of ferrous based alloys.

Anodizing is a commonly used practice for providing a corrosion resistant coating on aluminum alloy products. The coating is applied by an electrolytic treatment of the base material in a conductive acidic-aqueous bath which produces an adherant film of aluminum oxide. The oxide is formed in useable thicknesses because microscopic pores are present during the electrolytic oxidation process which allows access of the electrolyte to the base metal.

After producing the coating the pores must be sealed or the protective capabilities of the coating would be seriously reduced. Sealing is normally accomplished by immersing the product in 180-200°F water for 30 minutes. This treatment hydrates the aluminum oxide thereby changing its structure causing the pores to close. One of the most commonly used tests for determining the presence of an anodic film is electrical conductivity. Since aluminum oxide is a dielectric, the surface of the product will not conduct if the coating is present. This test is rapid and convienent; however, it will not detect the lack of adequate sealing since the pore size is too small for electrical probes to be effective.

Information detailed below and in the subsequent photomicrographs illustrate the findings of this series of tests. The more important findings are summarized below and in Table I.

TABLE I

MATERIALS COMPATIBILITY EXPOSED TO N_2O_4 AT 275°F FOR 30 HOURS

1.	2014-T6	Aluminum, Chromic Acid Anodized	C
2.	2014-T6	Aluminum, Sulfuric Acid Anodized	C
3.	6061-T6	Aluminum, Chromic Acid Anodized	C
4.	6061-T6	Aluminum, Sulfuric Acid Anodized	C
5.	2021-T6	Aluminum, Chromic Acid Anodized	N/A
6.	2021-T6	Aluminum, Sulfuric Acid Anodized	C
7.	6061	Aluminum, Screen Chromic Acid Anodized	C
8.	6061	Aluminum, Screen Sulfuric Acid Anodized	N/A
9.	2024-T3	Aluminum, Pure Aluminum Clad	C
10.	2024-T3	Aluminum, Clad Stripped	NC
11.	430	Stainless Steel	C
12.	321	Stainless Steel, Chrome Plated	MC
13.	AMS 5538	Stainless Steel	MC
14.	21-6-9	Stainless Steel	MC
15.	HY-140	Steel	C
16.	Titanium 5 Al-2.5 Su		C
17.	Titanium 8 Al-1 Mo		C
18.	Beryllium		C
19.	Columbium DP14		C
20.	Columbium CB752		C
21.	Tantalum, Pure		C
22.	Tungsten, Pure		C
23.	TAM Titanium-Zirconium-Molybdenum		MC
24.	L-605 Cobalt		MC
25.	Beryllium Oxide Ceramic		C
26.	Aluminum, Oxide Ceramic		C

C - Compatible

MC - Marginally Compatible

NC - Not Compatible

N/A - Not Available. Specimen improperly prepared.

(a) Anodic coating of aluminum alloys can insure almost 100% protection to these materials.

(b) Commercially pure aluminum cladding of structural aluminum alloys provides 100% protection with a very slight amount of corrosion products formed. The formation of corrosion products was so small the material may be classified as compatible.

(c) Tantallum and columbium were unaffected by the propellant. Both of these materials are highly ductile and would be capable of producing high quality screens for positive displacement devices.

(d) Chromium plating stainless steels affords excellent protection to the base material although only 321 stainless steel was tested. This protection could be afforded to any metallic material.

(e) L-605 cobalt alloy sustained weld surface attack and may be considered marginally compatible. It in no way resembled the poor corrosion resistance of the high nickel ferrous alloys.

Test Conditions

All specimens were exposed to nitrogen tetroxide (N_2O_4) which had been treated with nitric oxide. Extreme care was taken to insure that test vessels were purged with dry nitrogen in order to prevent the propellant from reacting with airborne moisture during loading. Test containers were then sealed and placed in a special chamber at 275$\pm$ 1^{o}F. This exposure was maintained for 600 continuous hours. Test containers were constructed from one-inch 6061-T6 aluminum tubing. Ends of the tubing were closed with AN flared tubing fittings. Test specimens were contained in a pyrex test tube in order to eliminate any influence of dissimilar metals.

Test Specimens

Specimens were tested in the stressed (75% of yield) condition and/or in unstressed configurations. Whenever possible, the NASA Langley

type specimens were used. When the physical properties of the material or ava ibility of shape were such that this specimen configuration was impractical, the material was tested without stressing.

Test Results

Materials tested are identified below by alloy nomenclature and by the pretreatment afforded. Photomicrographs were taken as necessary to aid in specimen evaluation.

1. 2014-T6 Aluminum, Anodized with Chromic Acid.

No observable attack. Anodic coating was intact, as determined by electrical measurements which showed that the surface of the specimen was not conductive. Figure 1 shows a photomicrograph which is representative of the degree of protection afforded aluminum by the anodic coating produced by chromic acid.

2. 2014-T6 Aluminum Anodized with Sulfuric Acid.

No observable attack. Anodic coating was intact as determined by electrical testing. See Figure 2 for the photomicrograph which demonstrates the protection afforded.

3. 6061-T6 Aluminum Anodized with Chromic Acid.

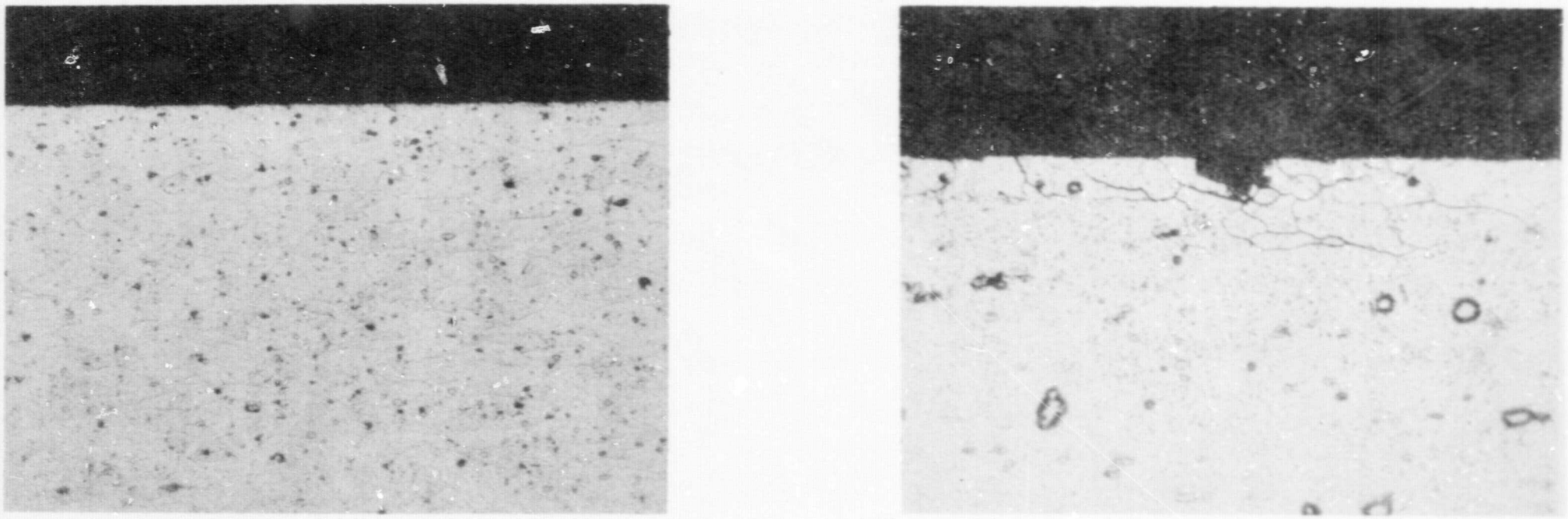
No observable attack. Anodic coating was intact.

4. 6061-T6 Aluminum Anodized with Sulfuric Acid.

No observable attack. Anodic coating was intact.

5. 2021-T6 Aluminum Anodized with Chromic Acid.

This specimen and the glass container had a light coating of an extremely fine, white powder. This indicated that a minute amount of the aluminum base material had been removed. Although the anodic coating was found to have remained (this was determined by conductivity measurements) it appears that the hot water seal was inadequate. This seal is performed subsequent to anodizing in order to close the pores formed during the process through hydration of the oxide film. It also points out the importance of an adequate seal for complete protection

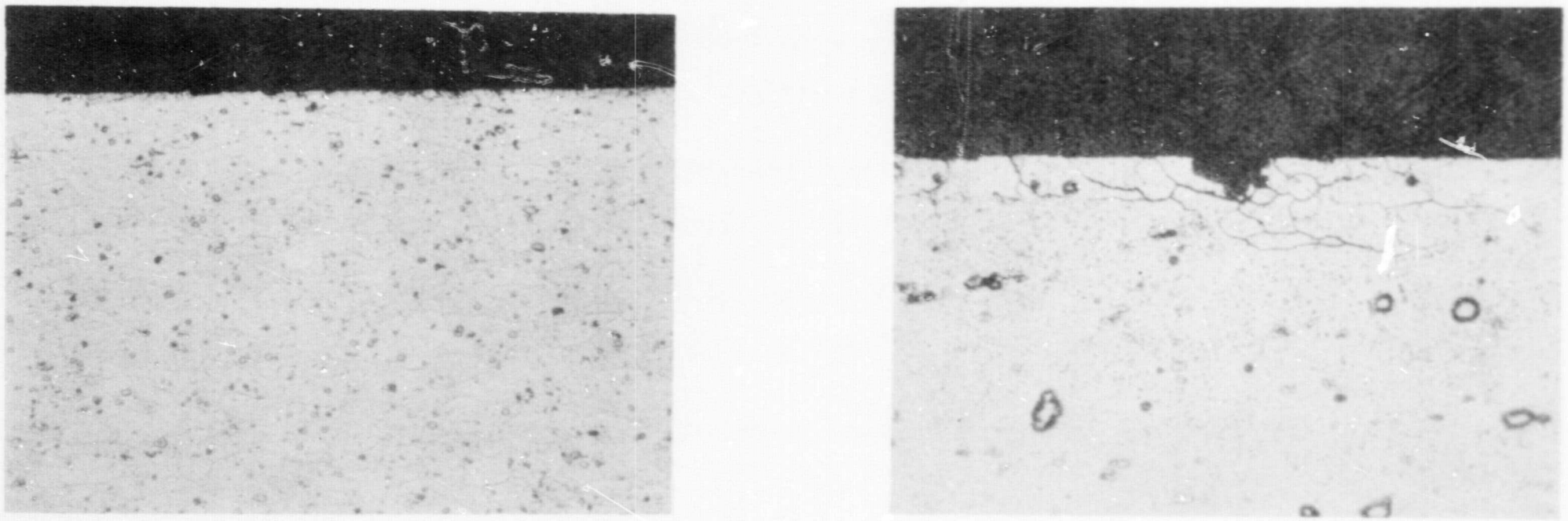


a. Chromic Acid Anodized

b. Bare Metal

No attack is noted on the chromic acid anodized aluminum

Fig. 1: Aluminum (2014-T6) After Exposure to N_2O_4 for 600 Hours at 275°F (200x)

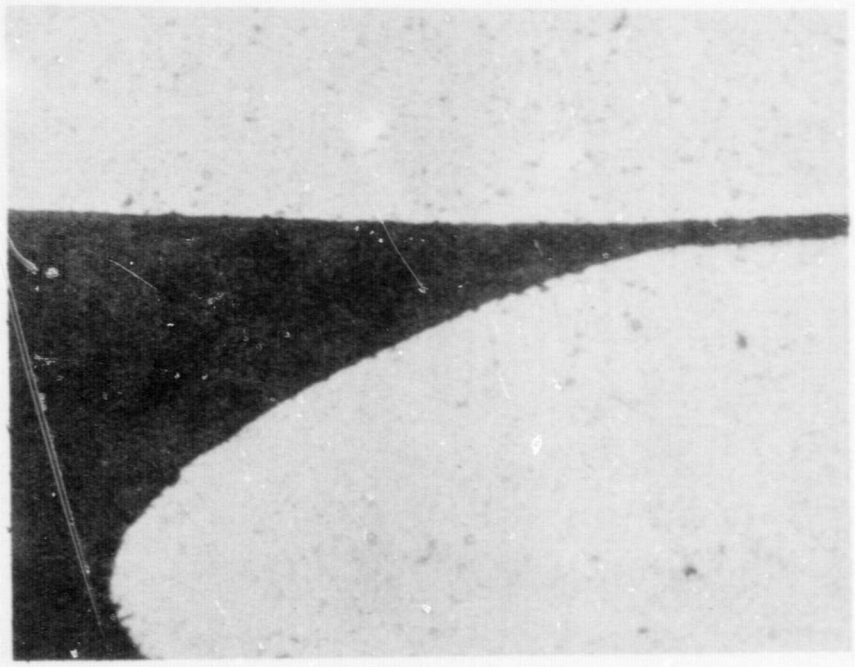


a. Sulfuric Acid Anodize

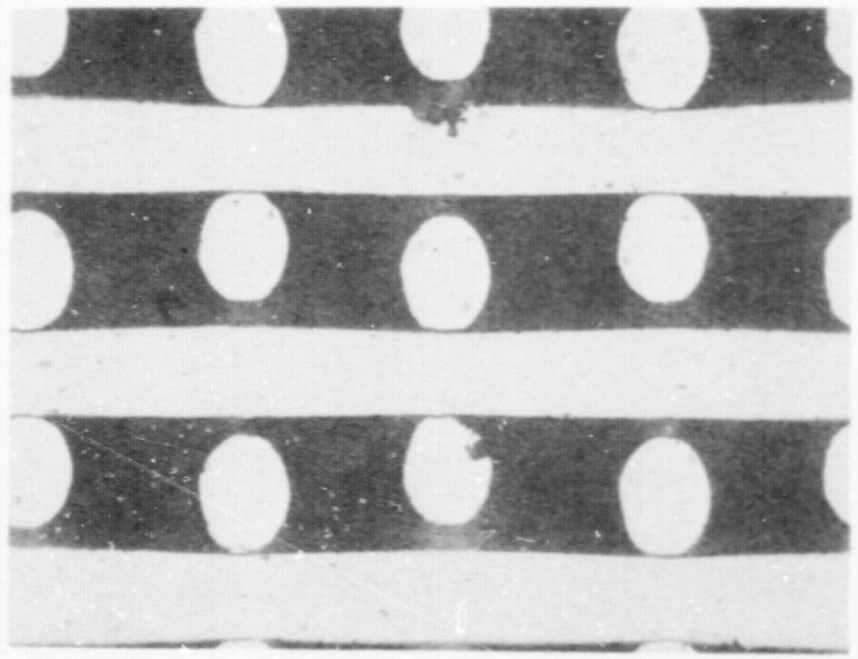
b. Bare Metal

No attack is noted on the Sulfuric Acid Anodized Aluminum

Fig. 2: Aluminum (2014-T6) after Exposure to N_2O_4 for 600 Hours at 275°F (200x)



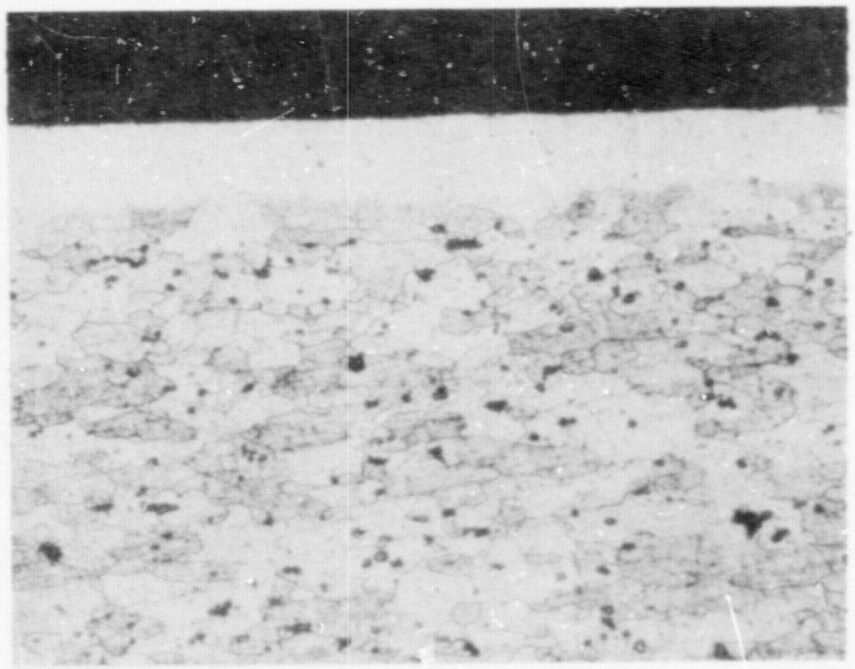
a. 6061 Alloy Chromic Acid Anodized



b. 5056 Alloy - Bare Metal

The Chromic Acid Anodized Specimen Sustained No Attack

Fig. 3: Aluminum Screen After Exposure to N_2O_4 for 600 Hours at 275°F (200x)



Surface is free of pits - there was no penetration of the clad coating

Fig. 4: Aluminum (2024-T3) Clad with Pure Aluminum After Exposure to N_2O_4 for 600 Hours at 275°F (200x)

of the base metal. Since this did not occur with the other wrought alloy specimens, it may be concluded that inadequate processing was the cause of the attack.

6. 2021-T6 Aluminum Anodized with Sulfuric Acid.

No observable attack. Anodic coating was intact.

7. 6061 Aluminum Screen Anodized with Chromic Acid.

No observable attack was found. Anodic coating was intact. See Figure 3 for a microsection of this specimen.

8. 6061 Aluminum Screen Anodized with Sulfuric Acid.

A light, powdery residue was found on the specimen and in the glass container indicating the same type of attack and incomplete processing as was found with the chromic acid anodized 2021-T6 wrought sample. Here again, the surface was not electrically conductive.

9. 2024-T3 Aluminum with a Commercially Pure Aluminum Clad.

Degree of attack was not significant. A minute amount of an externally fine powder was resident on the specimen surface. Figure 4 demonstrates the low degree of attack and the lack of any penetration of the cladding.

10. 2024-T3 Aluminum with Cladding Stripped Prior to Test.

Reacted typically of highly alloyed, unprotected aluminum structural alloys. This resulted in intergranular attack and formation of corrosion products.

Further testing of stainless steels was accomplished. As may be seen in the results of initial tests conducted during this contract, all candidate 300 series stainless steels were found to be unacceptable for use in the specified environment because of the formation of large quantities of a thick, viscous material. Chemical assay of this product showed that its elemental compsotion was the same as that of the test specimen.

The presence of a relatively high nickel content was suspected to cause the reaction. This series of tests were conducted in order to gain additional data related to the nickel content effect, the value of a protective coating, and to stainless steels other than the common 300 series alloys tested during the initial phase of this contract. Results are as follows:

11. 430 Stainless Steel.

This alloy sustained a minor degree of attack which resulted in superficial darkening of the specimen surface. There was no formation of any of the viscous corrosion product or of intergranular corrosion which was typical of the 300 series alloys. The surface darkening was primarily found in areas which were freshly sheared or had recently been shot peened. Since the specimen had been passivated prior to specimen preparation, and not after, this indicates that the specimen was more active in the freshly worked areas. Photomicrographs shown in Figures 5 and 6 were taken from a passivated surface (5) and a shot peened surface (6). As may be seen, no observable chemical attack existed on either area. The rougher appearance of Figure 6 is the result of the shot peening. This alloy may, for all practical purposes, be considered inert to the propellant sterilization environment.

12. 321 Stainless Steel, Chromium Plated.

A light attack was sustained with resultant formation of a minute amount of a viscous corrosion product. The amount of the product formed was less than 1% of that formed when bare 321 stainless steel was exposed to N_2O_4 during the sterilization cycle. Ordinarily, chromium plating is a poor protective coating against corrosion because of microscopic porosity inherent to this coating. This porosity apparently allowed the small degree of attack to take place. There are proprietary processes available which produce a crack-free chromium plating. Application of this type of coating could be of significant value in protecting the 300 series stainless steel alloys. Figure 7 illustrates the degree of protection provided by the standard plating process.

Fig. 5: 430 Stainless Steel Passivated Surface

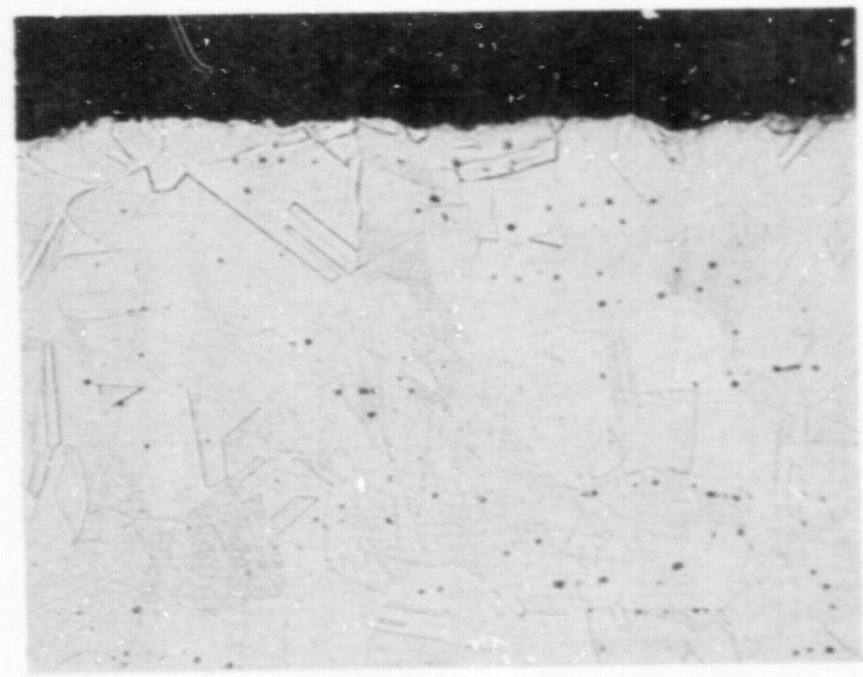
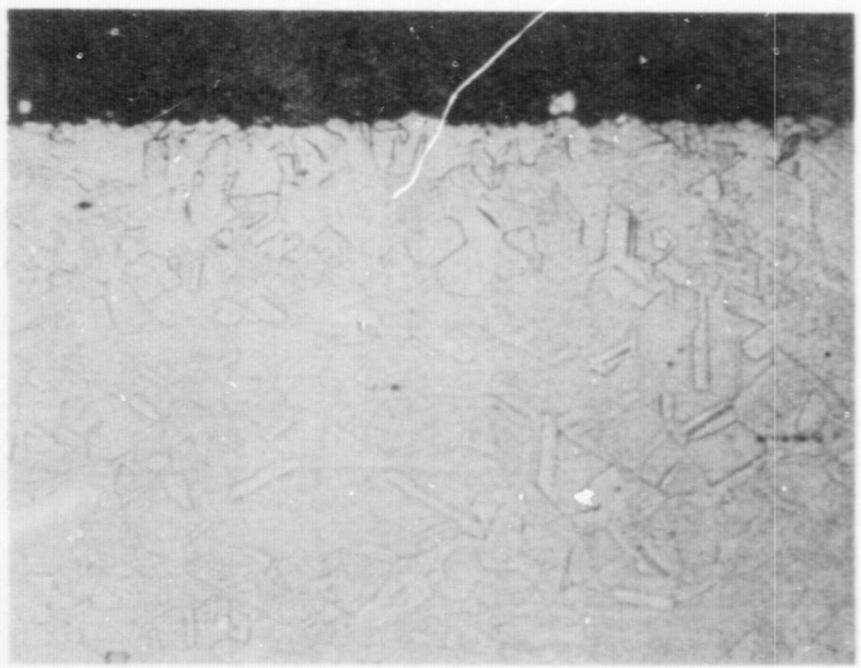
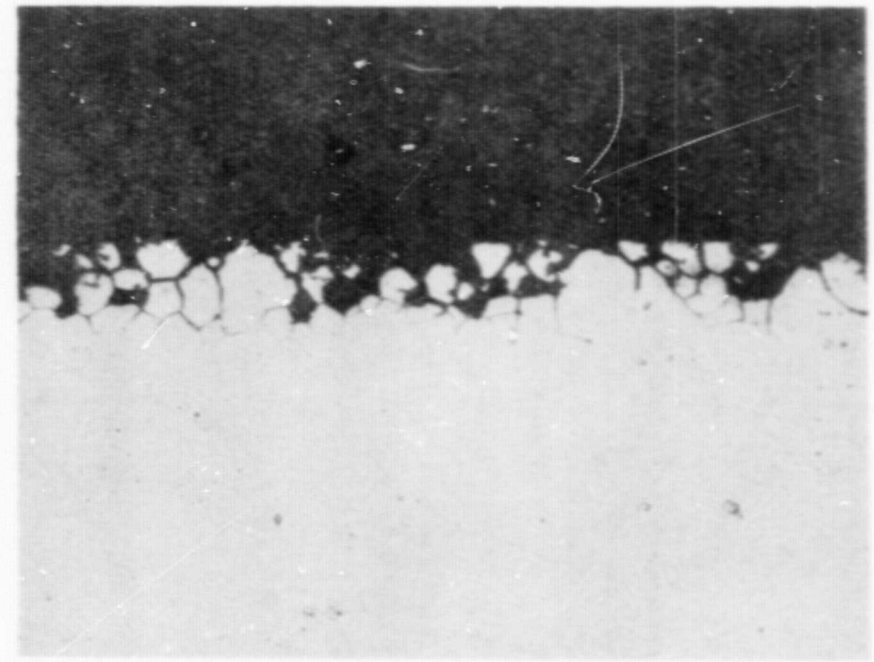


Fig. 6: 430 Stainless Steel Freshly Peened Surface

There was no evidence of intergranular attack or pitting in either Fig. 5 or 6. Surface roughness shown in Fig. 6 was the result of shot peening.



a. Chrome Plated



b. Bare Metal

The chrome plated specimen was not attacked.

The plating is shown as a dark surface in Fig. a.

Fig. 7: Stainless Steel (321 series) after Exposure to N_2O_4 for 600 Hours at 275°F (200x)

13. AMS 5538 Stainless Steel Alloy.

Surface attack was noted with resultant formation of a few beads of the viscous corrosion product and a general roughening of the specimen surface. This material was affected much less than were the bare 300 series alloys. Figure 8 illustrates the degree of attack.

14. 21-6-9 Stainless Steel Alloy.

Surface attack was sustained with formation of a few beads of the typical corrosion product. This material reacted in a manner similar to that of AMS 5538. Figure 9 illustrates the minor degree of attack as well of the lack of significant intergranular corrosion.

15. HY-140 (HY represents high yield strength of 140 Ksi)

In order to further pursue the idea that nickel may be a major contributor to the attack on ferrous alloys, a low alloyed material possessing excellent structural properties was tested. This specimen was polished to a mirror finish prior to the test. Upon removal from the propellant, this finish was unaffected. HY-140 demonstrated greater corrosion resistance than 6Al-4V titanium or any ferrous based alloy tested.

Since the 6Al-4V titanium had exhibited superior corrosion resistance to that of any alloy tested in the first series of this contract, it was determined that additional representative alloys of titanium be evaluated to establish whether this characteristic was typical of titanium. Results were as follows:

16. 5Al-2.5Sn Titanium Alloy.

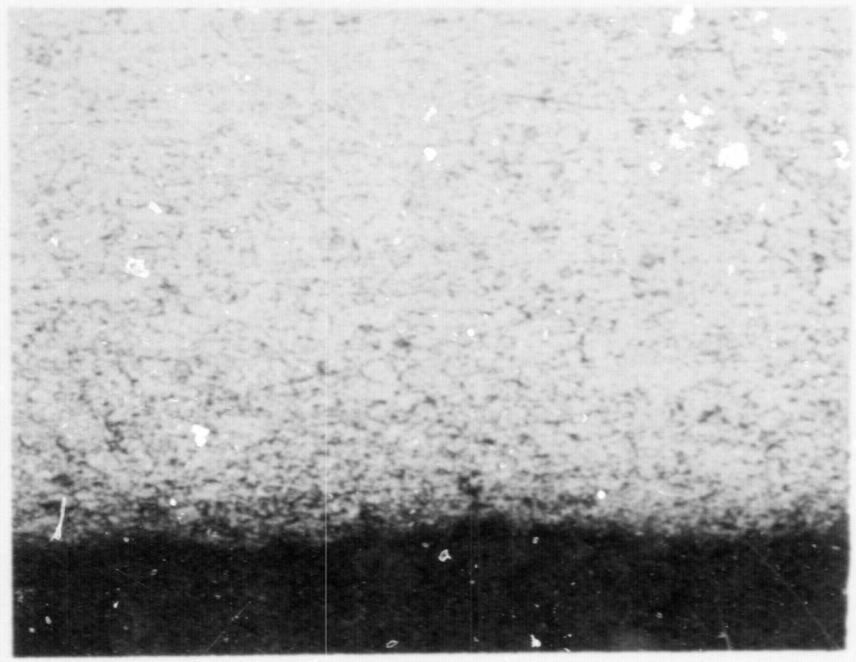
Light surface attack was found with the formation of an iridescent film which is typical of that formed on 6Al-4V titanium. Both alloys are considered comparable in resistance to attack by the propellant. Figure 10 demonstrates this alloys high degree of compatibility.

17. 8Al-1M Titanium Alloy.

This alloy reacted identically as that of 5Al-2.5Sn.

Surface attack is evidenced by small pits. No significant intergranular attack is apparent

Fig. 8: Stainless Steel (AMS 5538) after Exposure to N_2O_4 for 600 Hours at 275°F (200x)



Surface is roughened by pitting.
Some intergranular corrosion is observable
Structural strength not affected

Fig. 9: Stainless Steel (21-6-9) after Exposure to N_2O_4 for 600 Hours at 275°F (200x)

Another series of materials were selected for test because they were unique in relation to those previously tested. Results were as follows:

18. Beryllium

This metal was completely unaffected by the propellant. Initially, it was suspected that its exposure to N_2O_4 might cause a sufficient rate of reaction that extreme pressure would result in a closed vessel. Therefore, preliminary testing was conducted in an open beaker containing 100 cc of N_2O_4 and about one cubic inch of beryllium. This test container was allowed to vent, in contact with air, until all the propellant had evaporated (about 3 hours). No reaction was noted. This material may be considered inert to the propellant.

19. Columbium Alloy, DP-14.

Light surface attack with attendant discoloration was noted. No loose corrosion products were formed. Figure 11 illustrated the degree of corrosion resistance that this alloy possesses.

20. Columbium Alloy CB 752.

This alloy reacted identically as the DP-14 discussed above.

21. Tantalum Commercially Pure.

No attack occurred. Tantallum is inert to the propellant.

22. Tungsten, Commercially Pure.

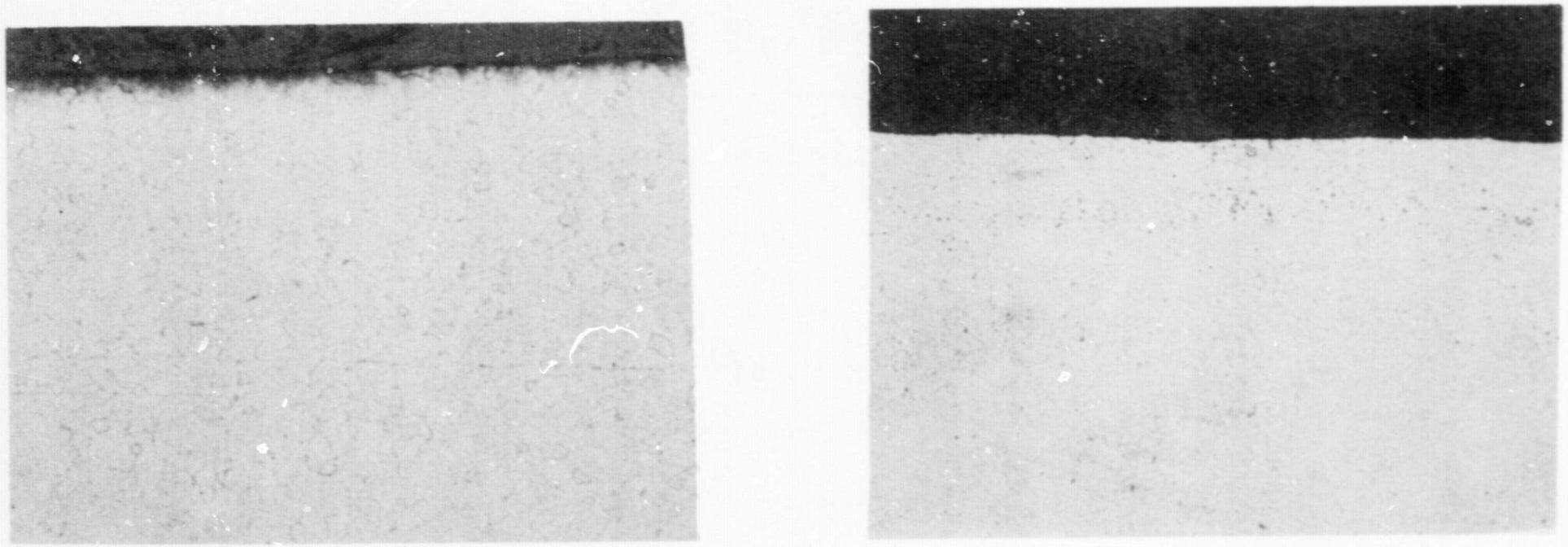
No attack occurred.

23. TZM (Titanium-Zirconium-Molybdenum).

A light surface attack with the formation of smut and some surface roughing was observed.

24. L-605 Cobalt Super Alloy.

Surface attack with formation of a white, loosely adherent corrosion product was noted. This alloy was tested, primarily because of its chemical simularity to nickel. Resultant corrosion products indicated cobalt behaves considerably different than nickel in the sterilization environment with N_2O_4. Figure 12 shows a photomicrograph of this material's surface after testing.

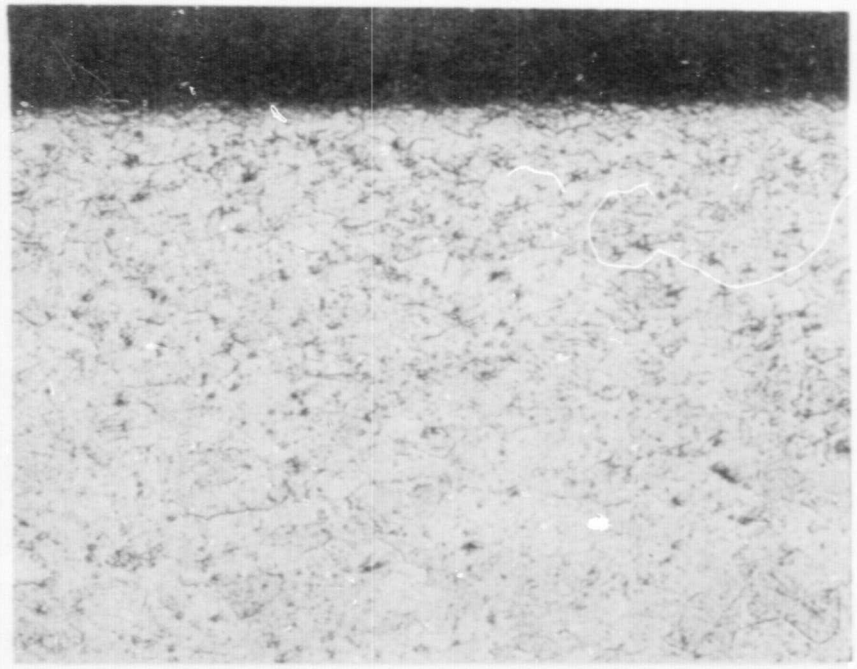


a. 5 Al - 2.5 Sn Alloy

b. 6 Al- 4 V Alloy

No evidence of attack of either alloy

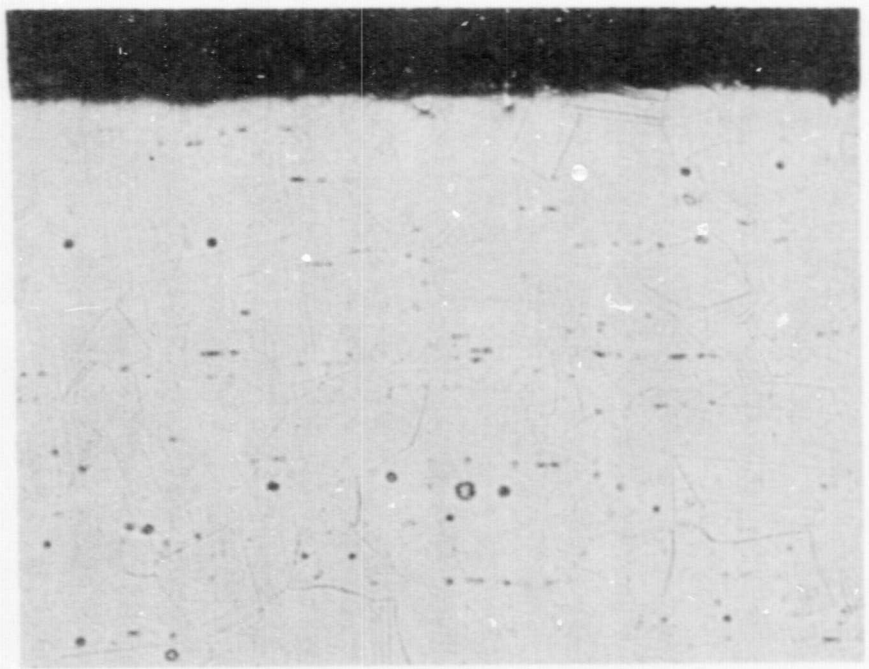
Fig. 10: Titanium Alloys after Exposure to N_2O_4 after 600 Hours at 275°F (200x)



No evidence of surface attack or intergranular corrosion observable.

The light attacked seen during surface examination was too small to be seen at 200x magnification.

Fig. 11: Columbium (DP-14) after Exposure to N_2O_4 for 600 Hours at 275°F (200x)



Some minute pitting of the surface is in evidence.
No intergranular corrosion occurred.

Fig. 12: Cobalt (L-605) after Exposure to N_2O_4 for 600 Hours at 275°F (200x)

25. Beryllium Oxide and Ceramic.

This material sustained no chemical attact and no increase in weight as the result of absorption. It is inert to the propellant.

26. Aluminum Oxide Ceramic.

This material sustained no chemical attack and no increase in weight as the result of absorption. It is inert to the propellant.

B. Oxidizer Tank Refurbishment

Both diaphragms were returned from the tank vendor for a detailed examination and sectioning. Enlarged cross sectional views of both diaphragms are shown in Figures 13 and 14. Figure 13 shows diaphragm S/N 101 and S/N 102 is shown in Figure 14.

Diaphragm S/N 102 was removed from the tank hemisphere before a leak was developed. Both diaphragms exhibit similar failures in that the normal membrane is in good condition clearly showing the laminate of FEP and TFE Teflon.

The failures of both diaphragms occurred in the same area, i.e., near the flange ring heat seal. In both instances, the failure occurred adjacent to the diaphragm rolled or formed flange. From the figures a heavier section of Teflon is noted where the Teflon is sprayed into the corner area of the mandrel.

The heat seal between the diaphragm membrane and the flange ring is accomplished by subjecting the clamped seal area to an induction heat processer until the temperature of the Teflon is raised to 450°F. This affords a seal between the FEP laminate of the membrane and a thin FEP layer which is the final coating sprayed on the ring which is normally a 50-50 codispersion mixture of Teflon.

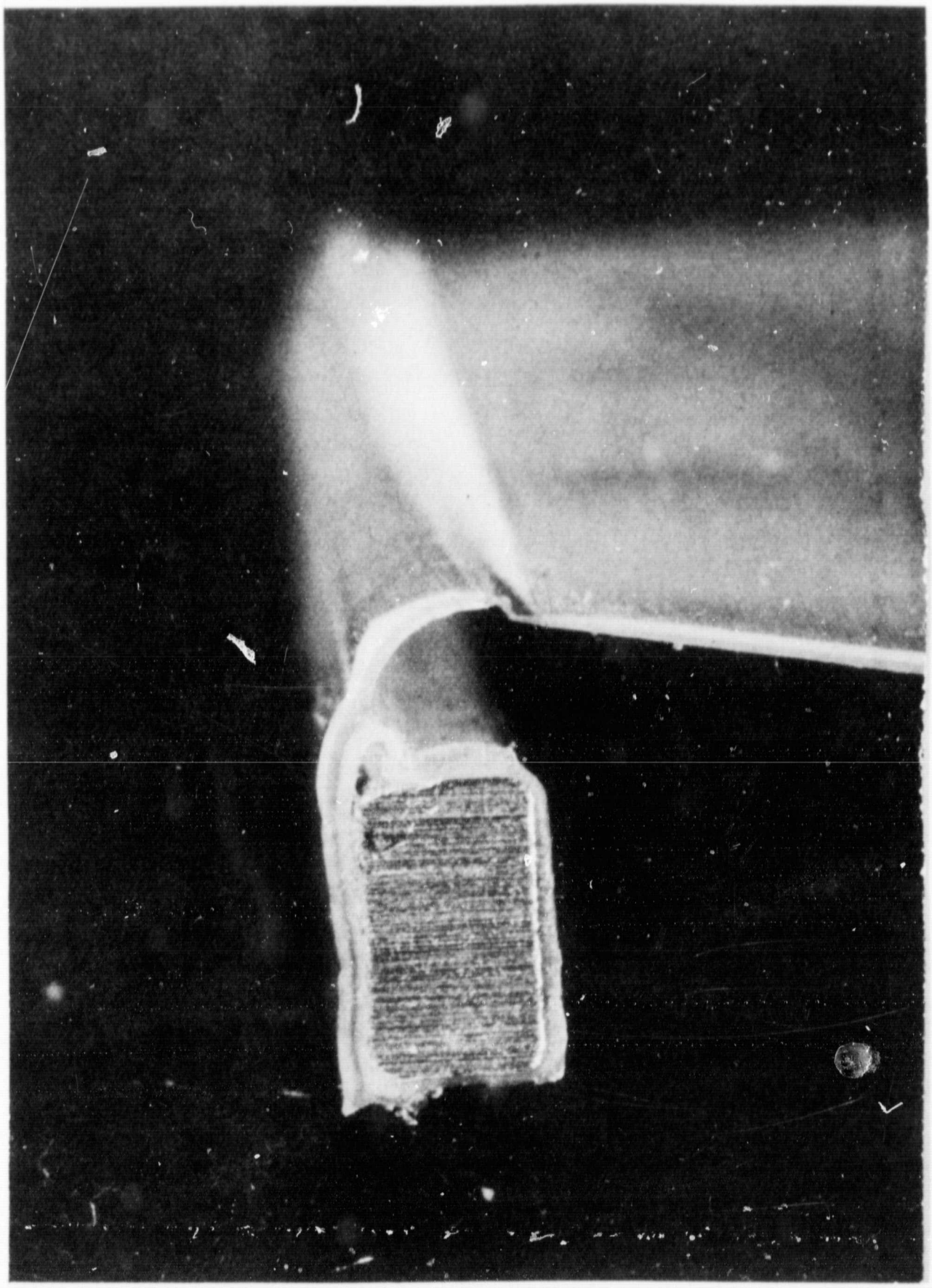
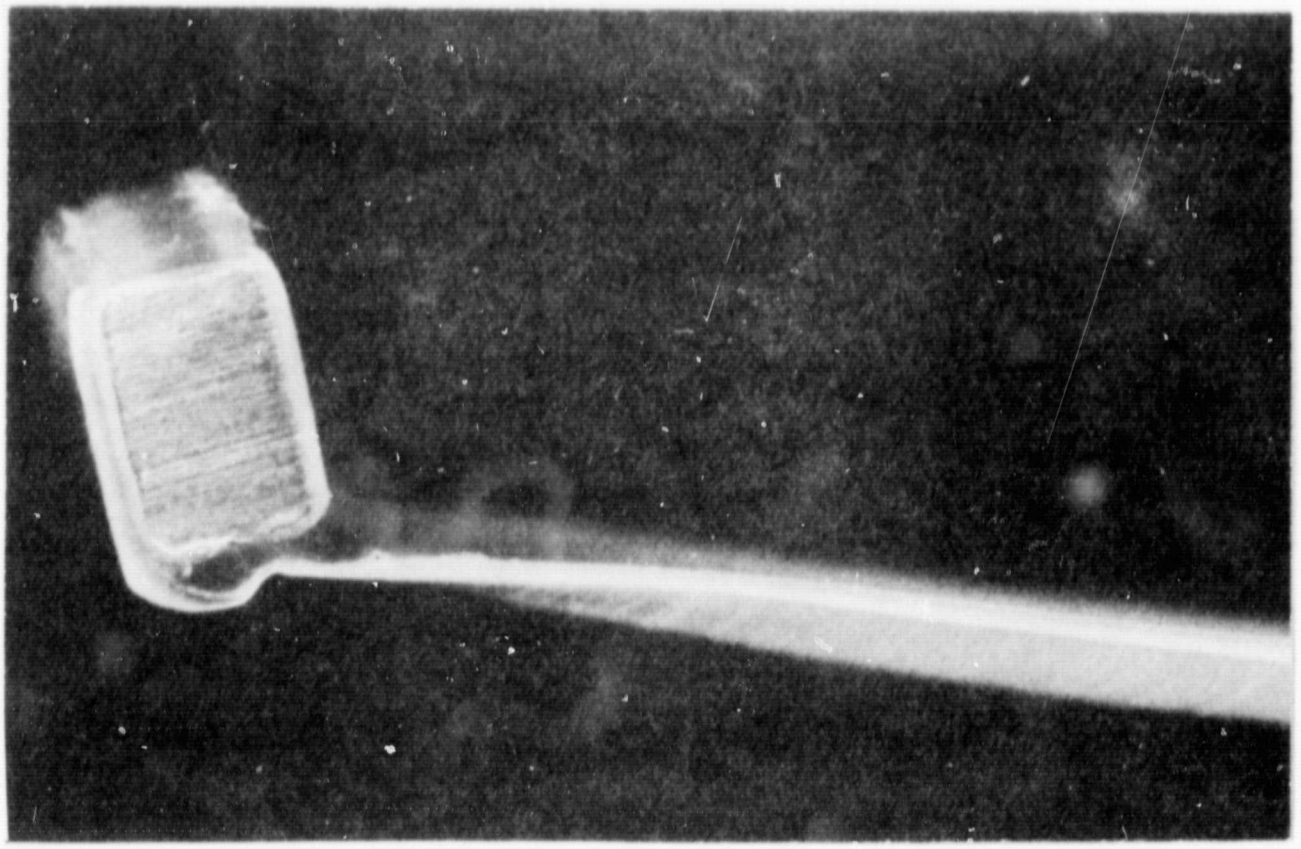


Fig. 13 Oxidizer Diaphragm S/N 101, Sectioned View



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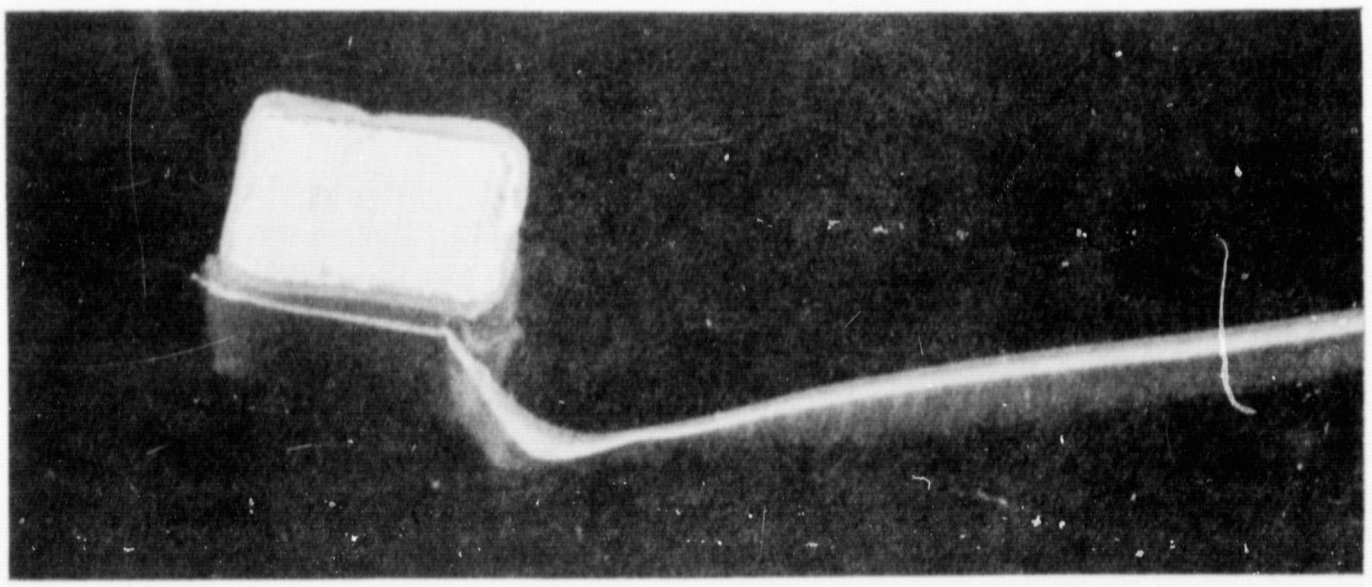

b

Fig. 14 Oxidizer Diaphragm S/N 102 Sectioned View

The condition of the S/N 101 ring flange seal suggests a deterioration of the seal area. It is not known whether the cause is due to the excessive heat at the corners of the ring resulting from the induction heating or whether excessive clamping loads were used. In any event the final condition is impossible to inspect for without destroying the diaphragm, the condition of S/N 102 does not show the same flow of Teflon around the ring flange yet the same procedure for heat sealing the flange to the diaphragm membrane was employed. The vendor implemented the pre-formed rolled flange on this diaphragm because an earlier configuration that was sprayed on a straight section caused ripples when the skirt was rolled over the flange ring.

The corrective action implemented was to size the diaphragms for a line-to-line contact at the normal inflation pressure thereby reducing the expected stress levels. This will reduce the loads imposed on the diaphragm at the natural stress concentration point at the flange ring seal. The diaphragms have been resized so that no more than 1% stretch is imposed from the relaxed condition of the membrane.

On 21 February the two Teflon diaphragms underwent successful acceptance testing at the Dielectrix Corporation. The condition of the heat seal of the diaphragm membrane to the Teflon coated ring flange was of a good quality on both units. There was no evidence of any bubbles in either unit.

The critical dimension, which was that of the spherical radius, of the diaphragm was achieved after several sizing operations by application of heat up to but not exceeding 300°F. The dimension under discussion is 8.250 $\pm$ 0.25 inches. Each unit was accepted at the upper limit of the tolerance. The units were shipped to the tank vendor, PSI, on 21 February 1969.

As a result of the diaphragm leakage and subsequent opening of the tank some material was lost. In order to build identical diaphragms it was necessary to reduce the height of both propellant tanks as dictated by the module tank LAB 6002514-89 which had to be remachined in preparation for rewelding. Final as-built determined the reduction in height of the -89 tank was 0.155 inches and for the remaining tank LAB 6002514-109 the reduction in height was 0.150 inches. A fit check of the diaphragms in each tank was satisfactory. The diaphragms in the relaxed condition barely touched the hemispherical wall which meant the line-to-line contact would be established with less than a 1% stretch.

New fixturing was provided for the tank assembly at this time. The fixtures were heavy duty rings with through bolts that provided assembly of the tanks with the necessary preload to seat the diaphragm ring seal. It also made it possible to make seal leak checks before welding so that repairs could be made if necessary without the expense of cutting the welded tanks apart. Preliminary checks were made before welding with GN_2 and it was established that no leaks occurred at the test pressure of 1 psig.

Both tanks were welded without incident and acceptance tested. During the acceptance testing there was no external leakage or deformation at the proof pressure of 2050 psig.

Some procedural difficulties were experienced in performing the internal diaphragm leakage tests. When the diaphragm is in a relaxed condition at ambient pressure some air is trapped inside the tank. When the diaphragm is pressurized to 1 psig on the liquid side the air on the pressurization side must escape which therefore may be interpreted as leakage by the uninitiated operator. The escape rate gradually lowers to a rate that may be interpreted as a permeation rate. If the rate remains high it can be interpreted as internal leakage. There is not enough data

available to establish a convincing permeation rate for the various Teflon laminates. Calculations for the geometric of this diaphragm would indicate a helium permeation rate of 15 ml/hr. This assumes a rate of 0.17 ml/in^2 - hr - psi - mil obtained from private conversations with Howard Standford of JPL. This rate was experimental data for FEP Teflon from DuPont. The module tank (-89) leakage was recorded as 5 bubbles of helium in 42 seconds. The tank was returned to the vendor (PSI) where the diaphragm was exposed to some higher internal pressures and retested with nitrogen. The final rate was .165 ml/hr. This compares to a calculated permeation rate for nitrogen of .15 ml/hr from the same reference noted above. The component tank (-109) leakage was recorded as .6 ml/min before proof test and 1.3 ml/min after proof test. This compared to 3.8 ml/min on the initial delivery in 1967. Therefore the same acceptance rationale prevails. The leakage rate is not detrimental to the firing time and the alternatives are too costly to consider. Therefore both tanks were accepted.

C. Module Refurbishment

Upon receipt of the -89 oxidizer tank the module refurbishment was initiated. At the close of the report period the progress has been on schedule.

Three minor changes have been made in the module configuration during this refurbishment.

1. A hand valve was substituted for one of the ordnance valves. This was necessitated by the unavailibility of sufficient number of valves. The substitution was made in the gaseous nitrogen system. This maintains the hermetic seal of the propellants. The hand valve was subjected to the sterilization environment earlier in the test program as a part of the test fixture of component test phase.

2. The small aluminum washers used in the serrated flange seal of the ordnance valves have been coated with 1 mil of Teflon. This seal leaked on several occasions during the previous sterilization exposure. It is hoped that the Teflon coating will prevent the leakage of the seal that was apparently due to the shock loading when the ordnance valve was actuated.

3. A material change from 6061-T6 aluminum to 300 series stainless steel was made in the tube connecting the hand valve to the interface panels on the fuel system only. This was a convenience change to allow easier tube bending and flaring. The change was not made on the oxidizer system since the hand valve is open during sterilization and 300 series stainless steel is not compatible with the oxidizer at 275^{o}F.

APPENDIX A

APPENDIX A

MONTHLY PROGRESS REPORT

PROGRESS REPORT FOR PERIOD 1 March through 31 March 1969

MILESTONE OR PROJECT TITLE Sterilizable Liquid Propulsion System

STATUS

The propellant tanks have been received from the vendor and rebuild of the module has been initiated. Rebuild is progressing on schedule with functional checks to be performed the first week of April.

Improper ordnance valves were received from JPL which has necessitated a substitution since no more ordnance valves of the proper part number were available. A manual valve will be placed in the nitrogen system so that hermetic sealing of the hazardous propellant systems is maintained.

During the next reporting period, the module checkout will be performed, sterilization will be completed and pre-firing checks will be completed. The next system firing date is scheduled for May 1, 1969.

A C Lukens

AUTHORIZED REPRESENTATIVE

APPENDIX B

MILESTONE PROGRESS REPORT

CONTRACTOR: MARTIN MARIETTA CORP., DENVER DIVISION
Denver, Colorado 80201

APPENDIX B

CONTRACT NO. 951709

FOR PERIOD ENDING: 31 March 1969

	MILESTONES (Key Task) (1)	MILESTONES WEIGHTED % (2)	MILESTONES ESTIMATED % OF COMPLETION (3)	TOTAL CONTRACT ESTIMATED % OF COMPLETION (4)	TECHNICAL EVALUATION (5)
1	Basic Contract	77.7	100.0	77.7	
2					
	Modification No. 1	22.3	70.0	15.6	▲
4					
5					
6					
7					
8					
9					
10					
11					
12					
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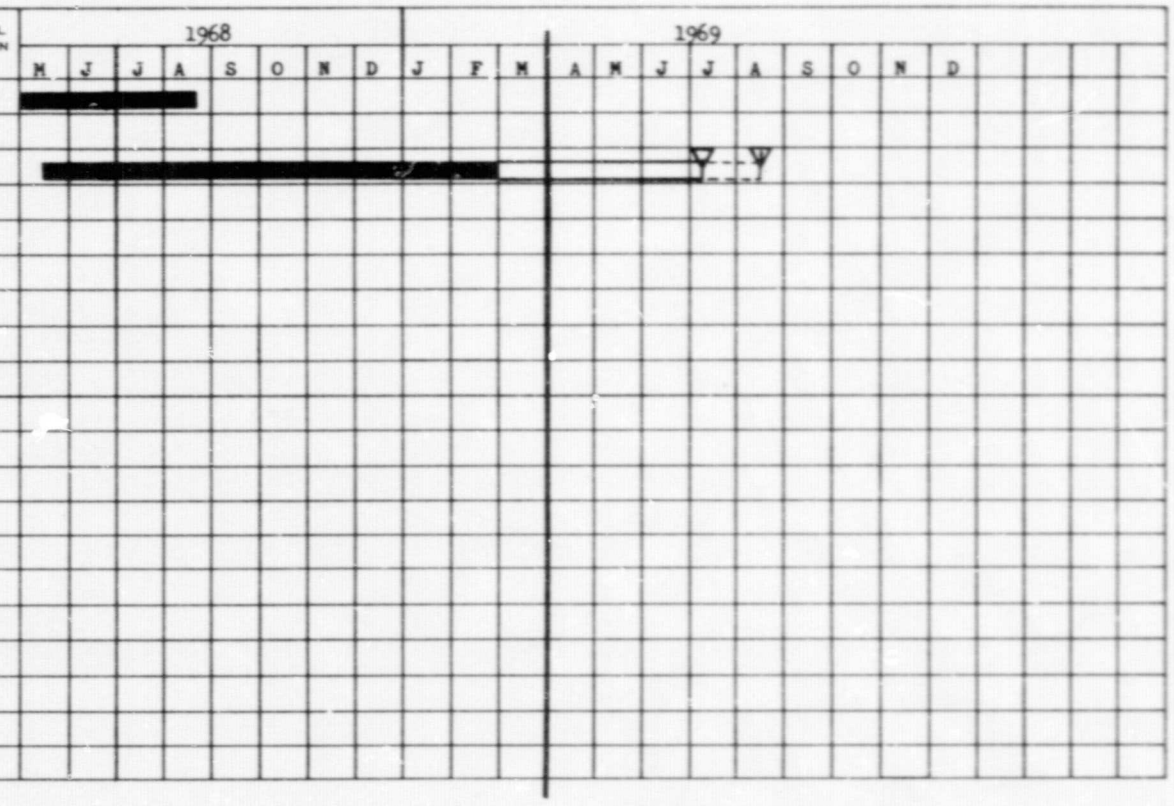
15					
16					
17					
18					
19					
20					
	TOTAL CONTRACT	100%		93.3	



DELIVERIES | DATE | STATUS

SCHEDULE LEGEND:
- SPAN TIME
- STATUS
- SCHEDULED
- COMPLETED
- RESCHEDULED
- SLIPPAGE ANTICIPATED
- ACTUAL SLIPPAGE

TECHNICAL EVALUATION SYMBOLS:
- SATISFACTORY PROGRESS
- SIGNIFICANT PROBLEM
- SERIOUS PROBLEM

REMARKS: 1) Request for change to Article 2 to reflect a completion date for the Technical effort of May 9, 1969 instead of April 4, 1969 was submitted 3/25/69 (MMC Reference: 9-Y-10911).

Approved: Samuel C. Lukens
Samuel C. Lukens
Program Manager